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Adsorption Studies for Removal of Uranium and Selenium

in

Rocky Flats Groundwater

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ADSORPTION STUDIES FOR REMOVAL OF URANIUM AND SELENIUM IN ROCKY FLATS GROUNDWATER

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Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM DIVISION

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1.0 INTRODUCTION

This Adsorption Treatability Study was performed under the Sitewide Treatability Studies Program (STSP), to determine the effectiveness of six adsorbent materials in removing uranium (U) and selenium (Se) from groundwater at the Rocky Flats Environmental Technologies Site (RFETS) These adsorbents were BIOFIX (immobilized biological agent), a natural Zeolite (Clinoptilolite), F-1 Alumina (granular activated aluminum oxide), Filtrasorb-300 (granular activated charcoal), Bone charcoal (R1022), and SORBPLUS (mixed metal oxide) (See Table 1 0-1) Groundwater samples for this study were collected from Wells GW3086 and B206789 which were known to be high in uranium (200 µg/l or 66 7 pCi/L) and selenium (600 µg/L) concentrations This groundwater was studied in laboratory scale column and batch tests

Table 1 0-1 Adsorbent Type

Adsorbent	Type (Common Name)	Manufacturer	Size-Mesh	Quantity (g)*
Filtrasorb 300	Granular Activated Carbon	Calgon Carbon Corp	12 x 40	30
F-1 Alumina	Granular Activated Alumina	ALCOA Industrial Chemicals	28 x 48	63
SORBPLUS	Mixed Metal Oxide	ALCOA Industrial Chemicals	20 x 40	61
BIOFIX	Immobilized Biological Agent	Amoco Performance Products, Inc	N/A	40
Bone Charcoal	R1022	Rockland International, Inc	N/A	53
Natural Zeolite	Clinoptilolite	East-West Minerals, Inc	20 x 35	68
* Amount Used in 2 5 cm x 15 cm Column				

This report focuses on the removal of uranium and selenium, although pertinent metals and anion data are also discussed Environmental Technologies and Environmental Engineering Technology conducted this work in accordance with the general guidelines of the Treatability Study Work Plan (TSWP) for Ion-Exchange Processes and Adsorption Processes (June 1993)

Previous work (Roushey, October 1993, Laul and Muller, October 1994) reported that filtering the groundwater (e g , Wells GW09091 and GW06991) through a 0 45 micron (µm) medium reduced the concentrations of plutonium (Pu) and americium (Am) below the potential Applicable or Relevant and Appropriate Requirements (ARARs) of 0 05 pCi/L Plutonium and americium in

RFETS groundwater appeared to be associated with total suspended solids (TSSs) and/or in colloidal form The efficient removal of plutonium and americium, through a 0 45 µm medium filtration, was demonstrated by comparing filtered and unfi tered groundwater samples from Well GW09091 This well contained high concentrations of plutonium (10 to 350 pCi/L) and americium (10 to 40 pCi/L) Filtration reduced the concentrations below 0 05 pCi/L

Concentration of metals such as aluminum (Al), arsenic (As), copper (Cu), chromium (Cr), iron (Fe), lead (Pb), manganese (Mn), vanadium (V), and zinc (Zn) were reduced below their ARAR values by filtration through a 0 45 µm membrane These metals were also associated with TSS and/or colloids in the groundwater Their removal was verified by comparing the filtered and unfiltered waters from 13 groundwater wells that contained high concentrations of the metals of concern These were groundwater Wells 0386, 03691, 01491, 05691, 1786, 2286, 3886, 4086, 7287, 12491, 13491, B206789, and B400389

This filtration was an effective process for treating RFETS groundwater to meet the potential ARARs with respect to the metals of concern, plutonium, and americium However, uranium and selenium were present in the same concentrations in the filtered and unfiltered groundwater samples Therefore, this study examined the effectiveness of six adsorbents in column and batch tests on filtered samples to reduce the concentrations of uranium and selenium in RFETS groundwater Based on column performance, batch tests (Kd, partition coefficient) with adsorbent weight to solution volume ratios of 1 50, 1 100, 1 200, 1 400, and 1 1000 were conducted to evaluate the relative loading capacities and adsorption isotherms of the effective adsorbents

The adsorption column tests demonstrated that uranium could be effectively removed (>99 9 percent) by four adsorbents (1) Bone Charcoal (R1022), (2) F-1 Alumina (Granular Activated Aluminum), (3) BIOFIX (Immobilized Biological Agent), and (4) SORBPLUS (Mixed Metaloxide), while selenium could be removed only by SORBPLUS Based on the column, batch and pH values, F-1 Alumina (Kd 1 0 x 10^4 ml/g and pH 7 9) and BIOFIX (Kd 2 2 x 10^4 ml/g and pH 6 6 to 7 5) appeared to be the best adsorbents for the effective removal (>99 9 percent) of uranium SORBPLUS had a high batch Kd (distribution coefficient) value of 2 1 x 10^6 ml/g for uranium, but the effluent pH was high (9 5 to 11 6) A combination of SORBPLUS (5 to 10 percent) with F-1 Alumina or BIOFIX (90 to 95 percent) may be a viable option to achieve the

maximum efficiency for uranium removal from RFETS groundwater SORBPLUS was marginally effective for selenium removal with a batch Kd value of approximately 40 ml/g

1.1 SITE DESCRIPTION

1.1.1 Site Name and Description

RFETS, a 6,550 acre industrial reservation, is located in northern Jefferson County, Colorado RFETS lies on Alluvium and Arapahoe bedrock, two major geological geostrata units The Alluvium consists of weathered claystone (Kacl) and the underlying Arapahoe bedrock consists of weathered and unweathered sandstone (Kass) Based on the geology and stratigraphy, the Alluvium units are more permeable to groundwater than the Arapahoe bedrock units (U S DOE 1991, 1992)

Groundwater sampling was conducted from March to June of 1994 Monitoring Well GW3086 is in the vicinity of the Solar Evaporation Ponds (SEPs) and is located in Operable Unit (OU) 8 The well penetrated 14 9 ft to the Arapahoe formation The pH of water from Well GW3086 was 7 6, indicating a predominance of a bicarbonate medium Its TDS was 3800 mg/L The uranium concentration in water from Well GW3086 was 200 µg/L (56 7 pCi/L) which has been the greatest among all wells sampled to date Pu-239 and Am-241 concentrations in the filtered and unfiltered samples from GW3086 were below the potential ARAR value of 0 05 pCi/L All the other Contaminants of Concern (COC) (i e , Be, Cr, Fe, Pb, Mn, Hg, and Se) were below their potential ARARs in the filtered water

B206789 is a monitoring well in the vicinity of Landfill Pond in OU7 It penetrated 20 ft to the Arapahoe formation The U-238 level was 1 7 pCi/L (5 0 µg/L), and the Pu-239 and Am-241 concentrations were below 0 05 pCi/L in the filtered and unfiltered samples The other COC, except selenium, were also below their potential ARAR The selenium concentration was approximately 600 µg/L in the filtered and unfiltered waters The pH of the groundwater from Well B206789 was 7 8, indicating a predominance of a bicarbonate medium Its total dissolved solid (TDS) was 1200 mg/L

1.1.2 History of Operations

From the mid-1950s to the present, RFETS has been a government-owned (i e , Department of Energy (DOE)), contractor-operated facility which manufactured weapon components primarily from plutonium, uranium, beryllium, and stainless steels RFETS had also reprocessed certain plutonium residues for the recovery of weapons grade plutonium This process included a variety of chemicals, solvents, and their by-products, which resulted in waste streams and discharges

From the 1960s to the 1970s, five SEPs (i e , 207A, 207B North, 207 Center, 207 South, and 207C) were constructed These ponds received and stored liquid wastes and discharges from various buildings at RFETS The liquid waste streams contained radionuclides such as U-234, U-235, U-238, Pu-239+240, and Am-241 Liquid waste streams also included metals such as aluminum, lithium, manganese, potassium, strontium, selenium, zinc, and anions such as bicarbonate, chloride, nitrate/nitrite, and sulfate The concentrations of these radionuclides, metals, anions and TDS values varied widely over two orders of magnitude Over time, radionuclides, metals, and anions may have migrated into the subunits of the Alluvium and Arapahoe bedrock formations

1.2 WASTE STREAM DESCRIPTION

1.2.1 Waste Matrices

Since a filtration operation (<0 45 µm) was shown to be a viable method for removing plutonium, americium, and heavy metals, this study was limited to soluble contaminants (i e , uranium and selenium) The groundwater from Well GW3086 contained uranium at approximately 200 µg/L and selenium at <1 µg/L Well B206789 contained uranium at 5 µg/L and selenium at approximately 600 µg/L The concentrations of uranium and selenium were the same in the filtered and unfiltered samples, which indicated that they were present in dissolved (i e , soluble) form These filtered groundwater samples were used individually as the feed solution for the column and batch tests The concentrations of uranium and selenium, major cationic and anionic composition of the individual groundwater samples, and feed solution are shown below in Table 1 2 1-1

Table 1.2.1-1 Composition of Wells GW3086 and B206789

Analyte	Well GW3086	Well B206789
Uranium (µg/L)	200	5 0
Selenium (µg/L)	<1	600
Calcium (mg/L)	290	160
Potassium (mg/L)	31	3 6
Magnesium (mg/L)	83	44
Sodium (mg/L)	650	140
Bicarbonate (mg/L)	390	180
Nitrate (mg/L)	560	6 7
Chloride (mg/L)	110	72
Sulfate (mg/L)	220	590
Total Dissolved Solid (mg/L)	3800	1200
Total Suspended Solid (mg/L)	74	<5
pH	7 6	7 8

These concentrations were typical of RFETS groundwater compositions No precipitation was observed in the feed solution during the time the experimen s were conducted

1.2.2 Pollutants/Chemicals

The TSWP listed the metals and radionuclides of concern and the ARARs are shown in Table 1 2 2-1

Plutonium, americium, and most other metals of concern can be removed to below their ARAR by filtration through a 0 45 µm filter (Roushey, October 1993, Laul and Muller, July 1994) Only uranium (Well GW3086) and selenium (Well B206789) had concentrations in the filtered and unfiltered waters that remained unchanged and above the ARARs Six adsorbents, listed in the TSWP, were tested for their effectiveness in the removal of uranium and selenium (See Table 1 0-1)

Table 1.2.2-1 Potential ARAR for COC

Element	Potential ARAR
Beryllium	4 µg/L
Chromium	50 µg/L
Iron	300 µg/L
Lead	15 µg/L
Manganese	50 µg/L
Mercury	2 µg/L
Selenium	10 µg/L
Uranium (Total)	5 pCi/L
Plutonium	0 05 pCi/L
Americium	0 05 pCi/L

1.3 TREATMENT TECHNOLOGY DESCRIPTION

1.3.1 Treatment Process and Description

Bench scale studies involved column experiments with a continuous rate of flow and batch experiments with varying adsorbent weight to solution volume ratios Figure 1 3 1-1 shows a schematic of a column experiment The cylindrical column had a 2 5 centimeter (cm) diameter and was filled with a 15 cm height of adsorbent A peristaltic pump, with a constant flow of 1 5 to 2 0 milliliters per minute (ml/min), moved the feed solution through the column The bed volume occupied from 50 to 60 cubic centimeters (cc), which gave a column residence time of 20 to 30 minutes The treated effluent was collected in a one gallon plastic container for subsequent analysis

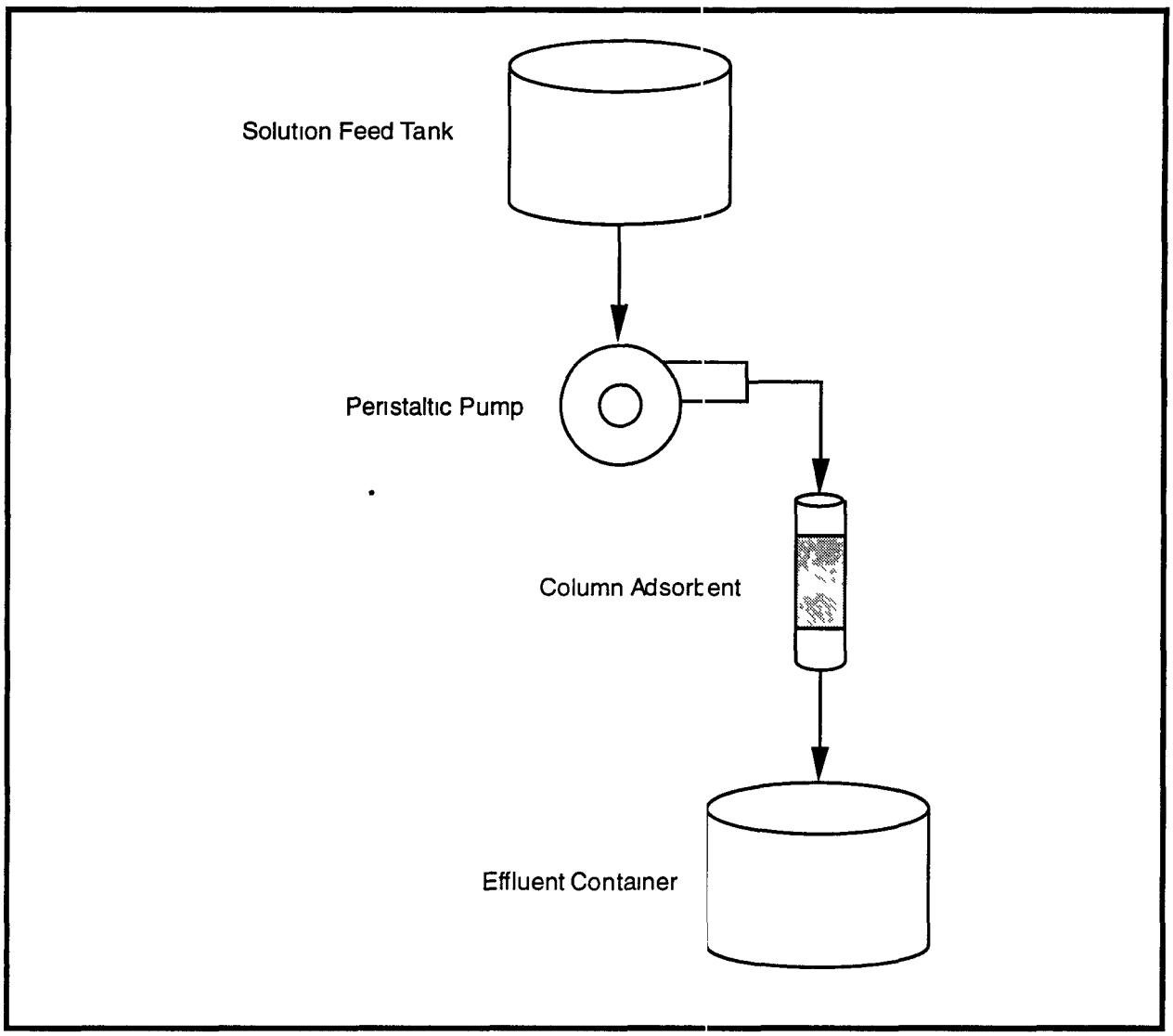

Figure 1.3.1-1 Schematic of Adsorption Treatability Tests

The column tests approximated a production treatment system while the batch experiments helped to select the best adsorbent for loading capacity The batch experiments consisted of adsorbent weight to solution volume ratios of 1 50, 1 100, 1 200, 1 400, and 1 1000 using 50 ml (100 ml for 1 1000) feed solution in a plastic bottle for each test The bottles were mounted on a tumbler and tumbled at thirty revolutions per minute for approximately 24 hours The solutions were then filtered through a 0 45 µm medium Aliquots were taken to determine pH and uranium and selenium concentrations using RFETS analytical facilities Also, one experiment for each of the four favorable resins was conducted using a large volume of feed solution (i e , 1 to 2 liters) and a

solid to volume ratio of 1 400 The analysis was performed by Accu-Lab Research, Inc , in Golden, Colorado, for various analytes – metals, radionuclides, anions, TDS, and pH (See Section 3 4 2)

1.3.2 Operating Features

Due to a slow recharge rate, groundwater samples from Wells GW3086 and B206789 were collected over a four to five day period in 10, one-gallon plastic containers The water samples from each well were filtered through a 0 45 µm membrane to form individual uniform samples The feed solutions were used for the column and batch tests to separately test for uranium and selenium with the six adsorbents The properties and specifications of the six adsorbents are shown in Table 1 0-1

The effluent volume collected was approximately fifty times the volume occupied by the adsorbent in the column The operating features for the column adsorption experiments are shown in Table 1 3 2-1

Table 1 3 2-1 Operating Features of the Column Experiments

Column Dimension	2 5 cm ID x 30 cm Height
Adsorbent Height	15 cm
Adsorbent Volume	50 – 60 cc
Feed Solution pH	7 6 for Well GW3086 7 8 for Well B206789
Solution Feed Rate	1 5 - 2 0 ml/Min
Column Residence Time	20 – 30 Minutes
Effluent Collected	2 4 Liters (50 Column Volumes)
Effluent pH	7 5 - 8 0 12 2 for SORBPLUS

The batch Kd experiments were performed with adsorbent weight to solution volume ratios of 1 50, 1 100, 1 200, and 1 400 using 50 ml of feed solution The mixtures, in plastic bottles, were tumbled for approximately 24 hours with a constant speed of thirty revolutions per minute The

solutions were then filtered through a 0 45 µm medium Different aliquots were taken for analysis of pH, uranium, and selenium

1.4 PREVIOUS TREATABILITY STUDIES AT THE SITE

For the majority of adsorbents, minimal information exists using RFETS groundwater regarding the removal of radionuclides (i e , Pu, Am, and U) and some metals (i e , Be, Cr, and Se) (See Table 1 4-1) The adsorption study was identified in the Final Treatability Studies Plan (FTSP) for evaluation at RFETS (August 1991) The TSWP for adsorption processes has identified six adsorbents (See Table 1 4-1) for evaluation to effectively remove metals and radionuclides of concern (i e , Be, Cr, Fe, Pb, Mn, Hg, Se, Am, Pu, and U) from RFETS groundwater

Table 1 4-1 Removal Effectiveness of the Adsorbents To Be Tested for the COC

Adsorbents	Type	Be	Cr	Fe	Pb	Mn	Hg	Se	Am	Pu	U
Filtrasorb 300	Granular Activated Carbon	NI	O	O	■	O	●	●	NI	NI	NI
SORBPLUS	Mixed-Metal Oxide	O	NI	O	O	O	O	●	O	O	NI
Natural Zeolite	Clinoptilolite	NI	O	●	●	■	●	O	NI	NI	O
BIOFIX	Immobilized Biological	NI	NI	●	●	●	●	O	NI	NI	■
F-1 Alumina	Granular Activated Alumina	NI	●	●	●	■	●	●	NI	NI	●
Bone Charcoal	Brimac 216	NI	O	●	●	●	●	O	NI	NI	NI

Legend
● Target Constituent
■ Potentially Effective
O Not Effective
NI No Information Available To Evaluate Potential Effectiveness

This Information is Taken from Figure 19-1, TSWP, June 1993

TSWP (June, 1993) identified the feed solution as a mixture of groundwater from Wells GW09091 (40 percent) and B206789 (30 percent) and surface water GS10 (30 percent) However, the previous adsorption study (Roushey, October 1993) showed that the levels of COC were too low for effective filter water testing A re-evaluation of the existing groundwater data,

from 1990 to present, stored in the Rocky Flats Environmental Data Base (RFEDS) was performed to identify wells and the levels of contaminants (COC) that would be suitable for treatability studies (Laul and Muller, October 1994) Groundwater from Well GW3086 (uranium) and Well B206789 (selenium) were selected for the adsorption study

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

This treatability study determined the effectiveness of six adsorbents in removing uranium and selenium from groundwater at RFETS Plutonium, americium, and heavy metals (i e , Al, As, Cu, Fe, Cr, Pb, Mn, V, and Zn) were associated with the TSS and/or in colloidal form They were removed below the potential ARARs by filtration through a 0 45 µm medium Among the 10 COC (i e , Be, Cr, Fe, Pb, Mn, Hg, Se, Pu, Am, and U), only uranium, in Well GW3086 (U 200 µg/L or 66 7 pCi/L) and selenium, in Well B206789 (Se 600 µg/L), had concentrations above their potential ARARs (i e , 5 pCi/L for U and 10 µg/L for Se) in the filtered and unfiltered groundwater samples

The column tests evaluated the effectiveness of six adsorbents on the filtered groundwater samples These tests identified four adsorbents which were effective in removing uranium below the 5 pCi/L potential ARAR value (1) Bone Charcoal, (2) BIOFIX, (3) F-1 Alumina, and (4) SORBPLUS

The retention factor (RF) is defined as the ratio of the solute concentration in the influent to solute concentration in the effluent, and is used a measure of removal effectiveness The RFs for uranium removal were 625 for Bone Charcoal, 1250 for BIOFIX (5000 if EG&G analytical result for uranium was used), 6670 for F-1 Alumina, and 10,000 for SORBPLUS The effluent pH values ranged from 7 4 to 8 3, except for SORBPLUS which had an effluent pH of 12 6 For this reason, F-1 Alumina and BIOFIX were the preferred adsorbents for uranium removal Natural zeolite (Clinoptilolite) and activated charcoal (Filtrasorb 300) had RF values of one which indicated they were ineffective in removing uranium from RFETS groundwater As a result, no batch tests were performed for these adsorbents

Batch experiments with adsorbent weight to solution volume ratios of 1 50, 1 100, 1 200, 1 400, and 1 1000 were performed to evaluate the adsorbents loading capacities and their adsorption isotherms The mean batch Kd and effluent pH values for uranium are shown as follows

Adsorbent	Kd	pH
Bone Charcoal	6.0×10^2 ml/g	7.7
F-1 Alumina	1.0×10^4 ml/g	7.9
BIOFIX	2.2×10^4 ml/g	7.5
SORBPLUS	2.1×10^6 ml/g	9.5 – 11.6

The most effective adsorbent, SORBPLUS, reduced the uranium concentration from 200 µg/L to 0.030 µg/L in a 1:400 batch test. However, the effluent pH increased the range between 9.5 – 11.6. The effluent pH values essentially did not change for the other three adsorbents. Bone Charcoal was the least effective adsorbent. However, it removed approximately 99 percent of the uranium content. For all four adsorbents, the effluent concentrations were below the potential ARAR (5 pCi/L or 15 µg/L). Batch tests indicated that F-1 Alumina and BIOFIX followed linear adsorption isotherms, whereas, SORBPLUS and Bone Charcoal followed a non-linear Langmuir, Fruendlich, or modified Langmuir isotherms (Sparito, 1980, Polzer et al, 1985, 1992).

Based on the column and batch experiments, F-1 Alumina and BIOFIX were the most suitable adsorbents tested for the effective removal (>99.9 percent) of uranium. SORBPLUS had the highest batch Kd value but its effluent pH was high. To offset the pH change, perhaps a mixture of SORBPLUS with F-1 Alumina or BIOFIX may provide an optimum performance condition.

SORBPLUS was the only adsorbent that was marginally effective in removing selenium from groundwater in Well B206789. The column (1:50) retention factor for SORBPLUS was >600, with an effluent pH of 11.8. However, the batch tests of 1:100, 1:200, and 1:400 ratios followed a linear isotherm and yielded a batch Kd value of approximately 40 ml/g, making SORBPLUS less favorable for selenium removal below the potential ARAR (10 µg/L).

2.2 RECOMMENDATIONS

This study identified four adsorbents for the removal of uranium from RFETS groundwater. Before the use of adsorbents individually or collectively on a larger scale operation, bench scale

experiments should be conducted to establish performance capabilities by determining break-through curves based upon batch Kd values For F-1 Alumina and BIOFIX, the adsorption isotherms were linear, so batch Kd validation with break-through curves will be easier For Bone Charcoal (R1022) and SORBPLUS, the adsorption isotherms followed a non-linear function, so break-through curves might follow a step function Therefore, the validation of batch Kd values is very important before testing an adsorbent on a large scale

The batch Kd values for uranium and selenium were established by evaluating individual RFETS groundwater samples If two groundwater samples (i e , Wells GW3086 and B206789) were combined and the same adsorbent is used to remove both elements, uranium and selenium would then be competing for the same adsorption sites The batch Kd values for uranium and selenium could remain the same or change from mixing two or more waters A separate experiment should be performed to establish the column retention factors and the associated batch Kd values for uranium and selenium

Adsorbent performance in a production environment requires a pilot scale study that could involve 1) Periodic analyses of the effluents to ensure that uranium and selenium concentrations are not exceeding their potential ARARs, 2) Optimum conditions (i e , pH and water feed rates) for using adsorbents to remove contaminants, 3) The loading capacities of the adsorbents at the optimum conditions, and 4) The performance of the adsorbents as a function of the COC concentration and the other major contaminants in solution which might affect its adsorptive capacities

The speciation of uranium and selenium in groundwater should be established The Ion-Exchange Study (Laul and Rupert, October, 1994) revealed that uranium and selenium are in an anionic form in the RFETS groundwater However, it is not known whether selenium is present as selenite (SeO_3^{--}) or selenate (SeO_4^{--}) The anionic form of uranium is also not known in groundwater

Per the manufacturers, these adsorbents can be regenerated and reused which could reduce the overall cost and also minimize secondary waste generation However, a regenerated adsorbent needs to be tested for its performance effectiveness to determine the number of times it can be used before it is replaced with a new adsorbent

3.0 TREATABILITY STUDY APPROACH

3.1 TEST OBJECTIVES AND RATIONALE

The objective of this study was to evaluate the effectiveness of six adsorbents as a remedial technology for the removal of radionuclides and metal COC from the RFETS groundwater These results could be integrated into the results into the Feasibility Study (FS) process for potential application to one or more OUs

Since previous work (Roushey, October 1993, Laul and Muller, October 1994) showed that plutonium, americium, and most other COC can be removed below the ARARs by filtration through a 0 45 µm medium, the focus was on uranium and selenium removal from Wells GW3086 and B206789, respectively The concentrations of uranium and selenium were unaffected by filtration The uranium concentration in GW3086 was 200 µg/L or 66 7 pCi/L, and its potential ARAR is 5 pCi/L The selenium concentration in Well B206789 was approximately 600 µg/L, and its potential ARAR is 10 µg/L

Groundwater samples from the two wells were evaluated separately so that only one contaminant had a high concentration The rationale for studying the groundwater separately was to establish the adsorbents' maximum retention factors and batch Kd values for defining their loading capacities and adsorption isotherm with a particular contaminant

3.2 EXPERIMENTAL DESIGN AND PROCEDURES

The study was conducted in three experimental phases (1) Phase 1 involved column experiments with a continuous downward feed solution flow, (2) Phase 2 involved batch experiments with a matrix of tests for each adsorbent with adsorbent weight to solution volume ratios of 1 50, 1 100, 1 200, 1 400, and 1 1000, and (3) Phase 3 repeated the batch experiment at the 1 400 ratio with a large volume (1 7 liters) of feed solution

The Phase 1 column tests simulated the performance characteristics of each adsorbent similar to its application as an applied remediation technology in the field All six adsorbents were tested in

Phase 1 Figure 1 3 1-1 shows a schematic of the column experiment The column description and operating parameters are outlined in Section 1 3 Using the EG&G analytical facilities, the effluents from each column were frequently analyzed to determine which adsorbents were retaining uranium Four adsorbents proved effective for uranium removal, Bone Charcoal, F-1 Alumina, BIOFIX, and SORBPLUS

The Phase 2 batch experiments were performed on each of the four favorable adsorbents with varied adsorbent weight to solution volume ratios to evaluate the relative partition coefficients and Kd values These test results helped define linear or non-lir ear isotherm models to establish relationships in adsorption processes The batch Kd values also provided information on the equilibrium state of uranium or selenium with the 20 to 30 minutes of residence time in the column tests Based on the comparison of the batch (1 50) and column tests, equilibrium was reached in the column experiments

Phase 3 involved a repeat of the batch experiment at a 1 400 ratio with a large volume (1 7 liters) of feed solution The effluent was analyzed for various analytes such as pH, TDS, metals, anions, total uranium and U-234 and U-238 by Accu-Labs Research, Inc, in Golden, Colorado

3.3 EQUIPMENT AND MATERIALS

The study used common laboratory glassware including plastic bottles, beakers (i e , glass and plastic), columns, and BIORAD peristaltic pumps The six adsorbents that were tested are listed in Table 1 0-1 The EG&G analytical equipment included a pH meter (Orion 230), a Kinetic Phosphorescence Analyzer (ChemCheck, KPA-11) for uranium analysis, and a graphite furnace atomic adsorption (GFAA) (Perkin Elmer, 5100Z) for selenium analysis

3.4 SAMPLING AND ANALYSIS

The sampling of groundwater from Wells GW3086 and B206789 was conducted according to proper groundwater sampling protocol by a subcontractor to the Environmental Restoration Program Division (ERPD) of EG&G, using operating procedure for groundwater sampling (OPS-GW-06, March 1992) Approximately 10 gallons of water were collected in the one gallon plastic

bottles from each well over a 4-5 day period The samples were taken to Treatability Laboratory 264 in Building 881 in accordance with Procedure OPS-4-11000-ER-OPS-F0 13 (Rev 2, May 1992) The samples from each individual wells were then filtered through a 0 45 µm membrane and stored individually for subsequent column and batch experiments

The pH values were measured using an Orion pH Meter that was calibrated, for each batch of samples, with standard buffer solutions with pH values of 7 and 10 The KPA-11 uranium analyzer was calibrated with uranium standards in the ppb range (33 3, 16 7, 8 33, and 3 33 ng/ml) to ensure consistency in the data A uranium standard 16 7 ng/ml was prepared at the beginning of each run as an internal standard in each batch of samples The KPA-11 is selective, rapid, and sensitive for uranium at or below the ppb level (0 1 pCi) A 10 percent error is associated with the results

For selenium analysis, five standards ranging from 25 to 200 µg/L were used for calibration (i e , non-linear) in each batch of samples The GFAA is also selective (using selenium lamp), rapid, and sensitive down to 1 µg/L or 1 ppb The sample injection required 0 020 ml and some samples were analyzed in duplicate Due to the low volume injections, the error ranged from 10 to 20 percent

The samples were also analyzed by Accu-Labs Research, Inc of Golden, Colorado for complete characterization of analytes such as pH, TSS, TDS, metals, anions, and radionuclides The analytes, their mode of measurement, equipment used, and the EPA approved reference method are shown in Table 3 4-1

3.4.1 Waste Stream

The only potential waste stream generated from this process would be spent adsorbent materials and any metals and radionuclides stripped from recycled adsorbents For a large scale treatment system, disposal of spent adsorbent materials could be a significant issue

Table 3.4-1 Method of Analysis by Accu-Labs Research, Inc.

Analyte and Mode	Equipment Used	EPA Ref Method
pH	pH Meter (Orion 720)	310 1
TDS by Gravimetric	Mettler AE200 Balance	160 1
TSS by Gravimetric	Mettler AE200 Balance	160 2
Metals by ICP		
Ag, Al, Ba, Be, Ca, Cd Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Sb, Tl, V, and Zn	Perkin Elmer 2000 Thermal Jarrell-Ash 61	200 7
Metals by GFAA		
As	Perkin Elmer 5000, 5000Z or 4100ZL	206 2
Se	Perkin Elmer 5000, 5000Z or 4100ZL	270 2
Pb	Perkin Elmer 5000, 5000Z or 4100ZL	239 2
Hg by Cold Vapor	Leeman PS200	245 1
Anions		
Alkalinity, CO_3, HCO_3 by Titration	Pipett, Burrette	310 1
Cl by Calorimetric	Technicon ASII Autoanalyzer	325 2
NO_3 by Calorimetric	Technicon ASII Autoanalyzer	353 2
SO_4 by Turbidimetric	Milton Roy Spec 301	375 4
Radionuclides		
Total Uranium by KPA	KPA-11, Chem Check	ASTM-D5174-91
U-238, U-234 by Radiochemistry	Alpha Spectrometry Nuclear Data and Canberra	Procedure*
Pu-239+240 and Am-241 by Radiochemistry	Alpha Spectrometry Nuclear Data and Canberra	Procedure*

*Procedures used for the analysis of radionuclides U-234, U-238, Pu-239+240, and Am-241 are standard radiochemical separations coupled with alpha spectrometry The results reported by Accu-Lab Research, Inc are shown in Appendix A.

3.4.2 Treatment Process

The treatment process is outlined in Section 1 3 1 The bench scale column test simulated actual field conditions, while batch tests yielded information on the loading capacities, break-through, and the nature of the adsorption isotherms

3.5 DATA MANAGEMENT

All the information pertinent to column and bench tests were recorded in a bound notebook The results of the uranium analysis (KPA-11) and the selenium analysis (GFAA) were processed internally The computers printed detailed information which was saved as a hard copy This data was also saved as a backup on the hard disk of the computer

Accu-Labs Research, Inc followed an Environmental Protection Agency (EPA) approved procedures and protocols for the analysis of various analytes listed in Table 3 4-1 All raw data was archived by Accu-Labs Research, Inc EG&G received the final data in report form (See Appendix A)

3.6 DEVIATION FROM THE WORK PLAN

There were some deviations from the Work Plan which were discussed and approved by DOE, the Colorado Department of Public Health and Environment (CDPHE), and EPA during the study

The Work Plan identified three groundwater wells (i e , GW09091, B206789, and GS10) in the respective proportions of 40 percent, 30 percent, and 30 percent as a feed solution to test six adsorbents for the removal of 10 COC (i e , Be, Cr, Fe, Pb, Mn, Hg, Se, U, Pu, and Am) As discussed in Section 1 4, the actual COC concentrations were considerably lower than indicated in the Work Plan (Roushey, October 1993) A re-evaluation of the RFEDS data identified wells and the concentrations of the COC (Laul and Muller, October 1994) It was noted that plutonium and americium in Well GW09091 and COC, such as Cr, Fe, Pb, and Mn in groundwater, were removed below their potential ARARs by filtration through a 0 45 µm medium The Be and Hg levels were already below their potential ARARs Therefore, this test work focused on uranium

and selenium Groundwater from Well GW3086 (uranium) and Well B206789 (selenium) were selected for analysis for this treatability study

The Work Plan specified that capability and capacity (i e , break-through) tests be performed by passing large volumes of feed solution at different flow rates through columns Because groundwater samples were limited (i e , slow rate of recharge), the same objectives were accomplished by the batch experiments with varying adsorbent weight to solution volume ratios of 1 50, 1 100, 1 200, 1 400, and 1 1000 using a small volume (50 ml) of feed solution Normally, one adsorbent weight to solution volume ratio is performed Four or five adsorbent weight to solution volume tests were performed to define an isotherm The Work Plan recommended that capability (i e , column tests) at three different pH values (pH 3 to 4, pH 6 to 7, and pH 9 to 10) be performed However, it was decided that column experiments using the natural pH (7 to 8) of the groundwater were more realistic for groundwater remediation studies at the RFETS

4.0 RESULTS AND DISCUSSION

4.1 DATA ANALYSIS AND INTERPRETATION

4.1.1 Well GW3086 for Uranium

4.1.1.1 Column Experiments—The uranium results of column experiments for the six adsorbents are shown in Table 4 1 1 1-1 The data from Accu-Labs Research, Inc for pH values, TSS, TDS, metals, anions, and radionuclides are shown in Appendix A The uranium concentration in the feed solution was 200 µg/L (66 7 pCi/L) Depending upon the effectiveness of the adsorbent, the uranium levels in the effluent ranged from 0 02 to 180 µg/L Four adsorbents showed a capability to remove uranium from the solution These four were (1) Bone Charcoal, (2) BIOFIX, (3) F-1 Alumina, and (4) SORBPLUS Filtrasorb 300 (activated charcoal) and Zeolite (Clinoptilolite) with RFs near 1 0 indicated no retention for uranium, therefore, no further batch tests were conducted for these adsorbents

Uranium values of EG&G generally agree with those of Accu-Lab Research, Inc The RFs ranged from approximately 1 to 10,000 The RFs for uranium removal were 625 for bone charcoal, 1250 (or 5000 based on EG&G data) for BIOFIX, 6670 for F-1 Alumina, and 10,000 for SORBPLUS Based on the high retention factors, SORBPLUS was the most effective adsorbent in removing uranium from the solution Since SORBPLUS was a mixed metal oxide, it yielded hydroxide anions in solution Therefore, the solution became quite basic (pH 12 6)

An effluent with a neutral pH can be discharged into the existing water system Therefore, adsorbents that yielded a near neutral effluent are preferred Except for SORBPLUS, the pH value of the effluents was between 7 4 and 8 3, close to the influent pH of 7 6 The SORBPLUS effluent pH of 12 6 was high This factor makes it less attractive despite a very high RF value

Table 4 1 1.1-1 Column Adsorption Experiments

Adsorbent	EG&G	Accu-Labs	RF (INF/EFF)*	pH*
Bone Charcoal (R1022)	0 27	0 32	625	8 3
F-1 Alumina (Granular Form)	0 03	0 03	6670	8 1
SORBPLUS (Mixed Metal Oxide)	0 02	0 02	10,000	12 6
Filtrasorb 300 (Activated Charcoal)	170	160	1 2	7 7
Natural Zeolite (Clinoptilolite)	180	180	1 1	8 0
BIOFIX (Immobilized Biological)	0 04	0 16	1250	7 4

*RF and pH Values are Based on Analytical Data from Accu-Labs Research, Inc

Parameters

Well GW3086 Feed Solution Total U-238 = 200 µg/L (66 7 pCi/L) pH 7 6

Column – 2 5 cm Diameter x 15 cm Height

Flow Rate = 1 5 to 2 0 ml/min

Volume Passed through = 2 4 Liter (50 Column Volumes)

The major cationic (i e , Na, K, Mg, and Ca) and anionic (i e , alkalinity, CO_3, HCO_3, Cl, NO_3, SO, and TDS) compositions of groundwater from Well GW3086 and the other four adsorbent effluents are shown in Table 4 1 1 1-2 The sodium and potassium concentration remained the same SORBPLUS showed a greater change in groundwater chemistry than the other three effective adsorbents The SORBPLUS effluent showed a significant increase in alkalinity and carbonate levels, and significant decrease in the magnesium, bicarbonate, chloride, nitrate, sulfate, and TDS concentrations Since SORBPLUS was a mixed-metal oxide, the observed changes in the cationic and anionic compositions suggested that substitution chemical reactions occurred

4.1.1.2 Batch Experiments—A series of batch tests were run to compare the four effective adsorbents Tables 4 1 1 2-1 and 4 1 1 2-2 summarize the batch tests for the varying adsorbent weight to solution volume ratios for uranium The pH values of each of the adsorbent weight to solution ratio are also included for comparison in these tables The mean batch Kd values for the four adsorbents and their pH values are shown in Table 4 1 1 2-3

Table 4.1.1.1-2 Major Cation and Anion Composition mg/L (Well GW3086 and Absorbent Effluents)

Analyte	Well GW3086	Bone Charcoal	BIOFIX	F-1 Alumina	SORBPLUS
Sodium	650	690	690	700	670
Potassium	31	36	33	32	32
Magnesium	83	130	76	65	1 4
Calcium	290	92	150	140	140
Alkalinity	320	280	120	180	1800
Carbonate	<5	<5	<5	<5	12
Bicarbonate	390	340	150	220	<5
Chloride	110	110	120	120	3
Nitrate	560	550	530	560	<0 05
Sulfate	220	190	210	80	<10
TDS	3800	3500	3700	3600	1800
pH	7 6	8 3	7 4	8 1	12 6

The batch Kd value is the ratio of an element's concentration in the solid phase (µg/g) to the liquid phase (µg/ml) and is shown in Table 4 1 1 2-4 The batch Kd value is expressed in units of ml/g The effectiveness of an adsorbent increases if the concentration of the solute in the effluent decreases As the retention factor increases, so does the magnitude of the batch Kd value, as shown in Figure 4 1 1 2-1 Therefore, the batch experiments provide information on the adsorbents relative loading capacities and adsorption isotherms for defining solid versus solution relationships

Table 4.1.1 2-1 Adsorption Experiments (Batch) for Uranium

Uranium-238 (µg/L)					
Ads Wt Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
Bone Charcoal					
1 50	200	12 7	15 7	$7\,4 \times 10^{2}$	7 8
1 100	200	25 7	7 8	$6\,8 \times 10^{2}$	7 8
1 200	200	50 0	4 0	$6\,0 \times 10^{2}$	7 7
1 400	200	100	2 0	$4\,0 \times 10^{2}$	7 7
1 400*	200	98 5	2 0	$4\,1 \times 10^{2}$	7 9
			Mean	$6\,0 \times 10^{2}$	
F-1 Alumina					
1 50	200	0 60	333	$1\,7 \times 10^{4}$	8 0
1 100	200	1 6	125	$1\,2 \times 10^{4}$	7 9
1 200	200	4 7	42 5	$8\,3 \times 10^{3}$	7 8
1 400	200	10	20 0	$7\,6 \times 10^{3}$	7 8
1 400*	200	12	16 7	$6\,3 \times 10^{3}$	7 5
1 1000	200	25	8 0	$7\,0 \times 10^{3}$	7 9
			Mean	$1\,0 \times 10^{4}$	

*Accu-Labs Research, Inc Data

$$\text{Batch Kd} = \frac{\text{Solid (µg/g)}}{\text{Liquid (µg/ml)}}$$

Table 4 1 1.2-2 Adsorption Experiments (Batch) for Uranium

Uranium-238 (µg/L)					
Ads Wt Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
BIOFIX					
1 50	200	0 74	270	1 3 x 10^4	6 6
1 100	200	0 74	270	2 6 x 10^4	6 9
1 200	200	1 2	167	3 3 x 10^4	7 1
1 400	200	4 0	50 0	1 9 x 10^4	7 4
1 400*	200	3 3	60 6	2 4 x 10^4	7 5
1 1000	200	10 6	18 9	1 8 x 10^4	7 4
			Mean	2 2 x 10^4	
SORBPLUS					
1 50	200	0 01	20,000	1 0 x 10^6	11 6
1 100	200	0 01	20,000	2 0 x 10^6	11.3
1 200	200	0 02	10,000	2 0 x 10^6	10 4
1 400	200	0 03	6,667	2 7 x 10^6	10 0
1 400*	200	0 03	6,667	2 7 x 10^6	8 2**
1 1000	200	0 74	270	2 7 x 10^5	9 5
			Mean	2 1 x 10^6	

*Accu-Labs Research, Inc Data

**Low pH Value May Be Due To Delay in Analysis

$$\text{Batch Kd} = \frac{\text{Solid (µg/g)}}{\text{Liquid (µg/ml)}}$$

Table 4.1 1.2-3 Adsorption Experiments (Batch) Comparison for Uranium

Uranium-238 (µg/L)		
Solid Volume	Mean Batch Kd (ml/g)	pH
Bone Charcoal	$6\ 0 \times 10^{2}$	7 7
F-1 Alumina	$1\ 0 \times 10^{4}$	7 9
BIOFIX	$2\ 2 \times 10^{4}$	6 6 – 7 5
SORBPLUS	$2\ 1 \times 10^{6}$	9 5 – 11 6

$$\text{Batch Kd} = \frac{\text{Solid (µg/g)}}{\text{Liquid (µg/ml)}}$$

Table 4.1 1 2-4 Batch Kd

$$\text{Batch Kd} = \frac{\text{Solid (µg/g)}}{\text{Liquid (µg/ml)}} = \frac{\text{ml (Influent – Effluent)}}{\text{g (Effluent)}}$$

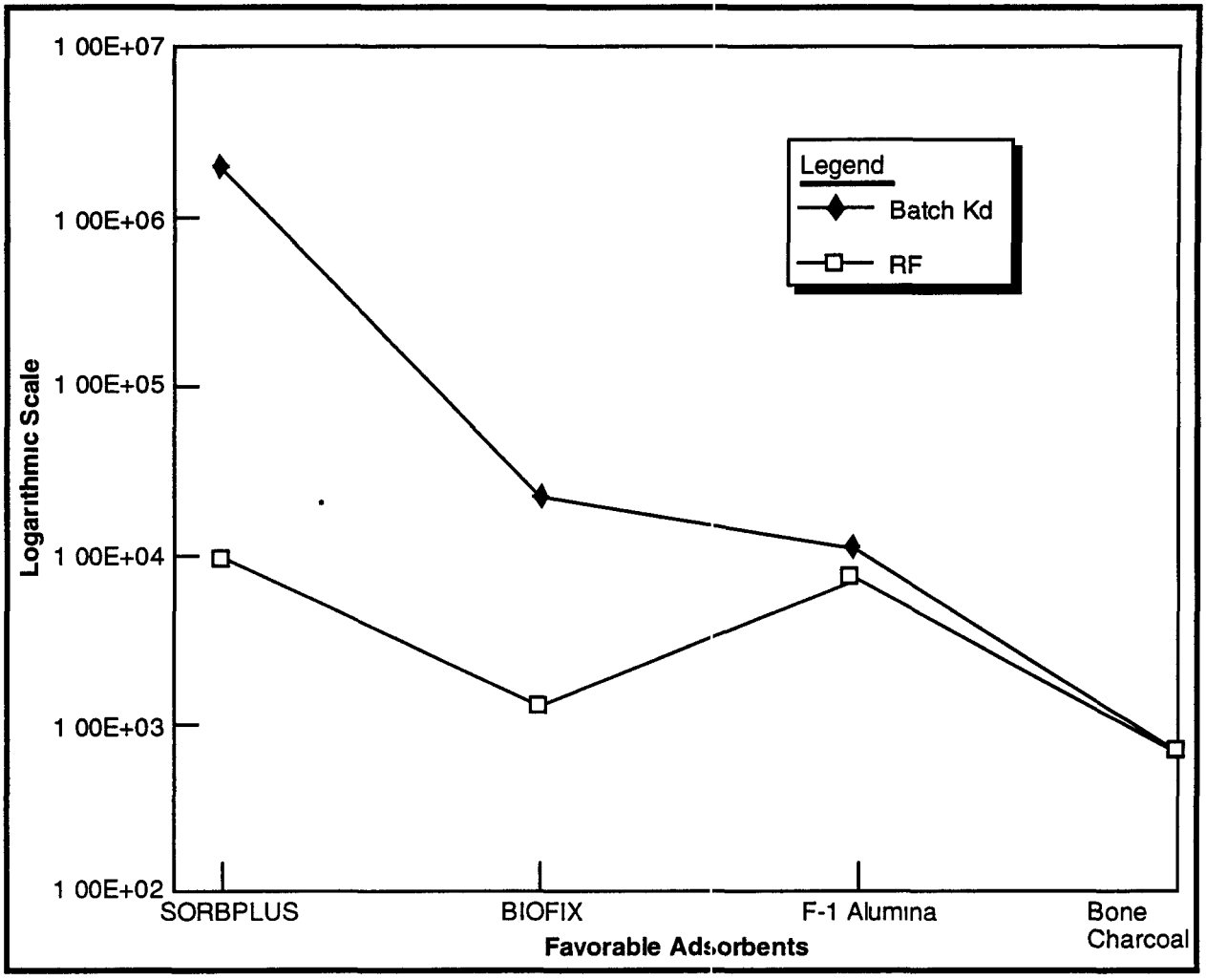

Figure 4 1.1.2-1 Batch Kd and RF Values for the Four Favorable Adsorbents

The batch Kd values (ml/g) for Bone Charcoal varied from 4 0 x 10^2 to 7 4 x 10^2, with a mean value of 6 0 x 10^2 (pH 7 8) The batch Kd values for F-1 Alumina varied from 7 6 x 10^3 to 1 7 x 10^4, with a mean value of 1 0 x 10^4 (pH 7 9) The batch Kd values for BIOFIX varied from 1 8 x 10^4 to 3 3 x 10^4, with a mean value of 2 2 x 10^4 (pH 6 6 through 7 5) The batch Kd values for SORBPLUS varied from 2 7 x 10^5 to 2 7 x 10^6, with a mean value of 2 1 x 10^6 (pH 9 5-11 6) The batch Kd values generally decreased when the solution volume increased This trend would be expected because there are more uranium atoms in the solu ion competing for the same adsorption sites

Equilibration relationships in sorption and ion-exchange processes have been described by isotherm models such as Linear, Langmuir, Freundlich, and Modified Langmuir (Sparito, 1980, Polzer et al, 1985, 1992) These models are as follows

Linear	$\text{Solid} = Kd \times \text{Liquid}$
Langmuir	$\text{Solid} = \dfrac{Kd \times \text{Liquid}}{1 + Kd \times \text{Liquid}}$
Fruendlich	$\text{Solid} = Kd \times \text{Liquid}^{(b)}$
Modified Langmuir	$\dfrac{\text{Solid}}{\text{Solid}_{max} - \text{Solid}} = Kd^{(b)} \times \text{Liquid}^{(b)}$

Fruendlich and modified Langmuir models are essentially the same (Kd and b are isotherm parameters) If the concentration of uranium adsorbed on the solid (µg/g) is plotted against the uranium in the liquid (µg/L), the slope of the line yields a batch Kd value (See Figure 4 1 1 2-2) F-1 Alumina and BIOFIX exhibit linear isotherms The slope of the lines yields the batch Kd value at equilibrium, which is similar to the mean batch Kd value shown in Table 4 1 1 2-3 Bone charcoal (R0122) and SORBPLUS, have linear relationships at lower uranium concentrations However, they have non-linear relationships at higher concentrations (See Figures 4 1 1 2-3 and 4 1 1 2-4) These patterns may follow Langmuir, Fruendlich, and modified Langmuir isotherm models (Sparito, 1980, Polzer et al, 1985, 1992)

To evaluate the relative effectiveness of the various adsorbents, RF, batch Kd, and pH values were used as criteria for selection Bone charcoal with a low batch Kd value of $6\,0 \times 10^2$ was the least attractive With a high Kd value in the range of about 1 to 2 $\times 10^4$ and a pH of 7 to 8, F-1 Alumina and BIOFIX were the most suitable adsorbents for an effective removal of uranium in groundwater at RFETS SORBPLUS had the highest batch Kd value of $2\,1 \times 10^6$ ml/g, but its effluent pH was

high (9 5 to 11 6) However, the effluent pH decreased with increased dilution A combination of SORBPLUS (5 to 10 percent) with F-1 Alumina or BIOFIX (90 to 95 percent) may be a viable option to achieve maximum efficiency

These adsorbents could be regenerated and reused, which could maximize their use and minimize their cost and generation of secondary waste streams The regeneration and re-performance tests were not conducted in this treatability study These studies should be performed as part of the remedy selection for the Remedy Design Treatability Study

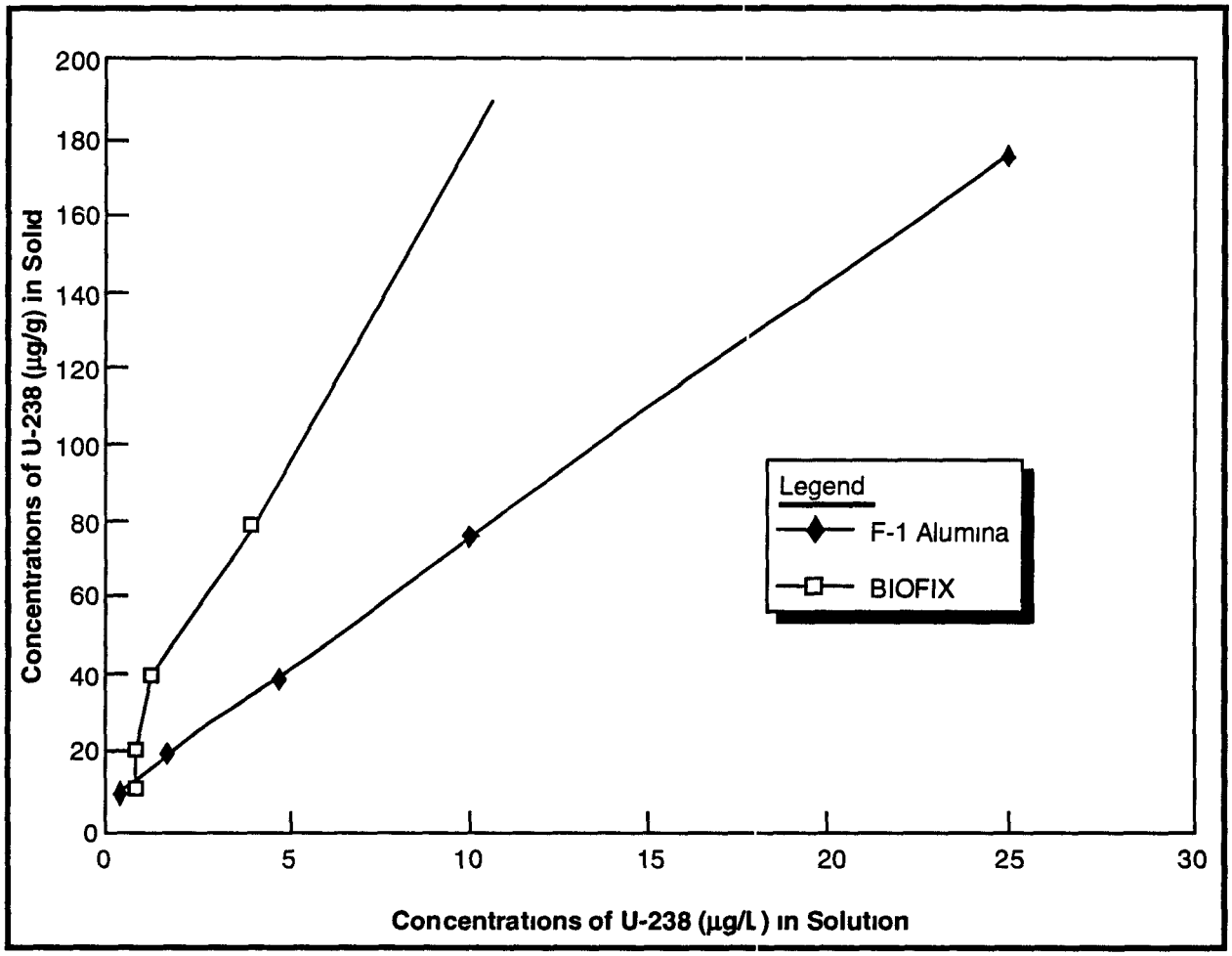

Figure 4.1 1.2-2 Isotherms for BIOFIX and F-1 Alumina

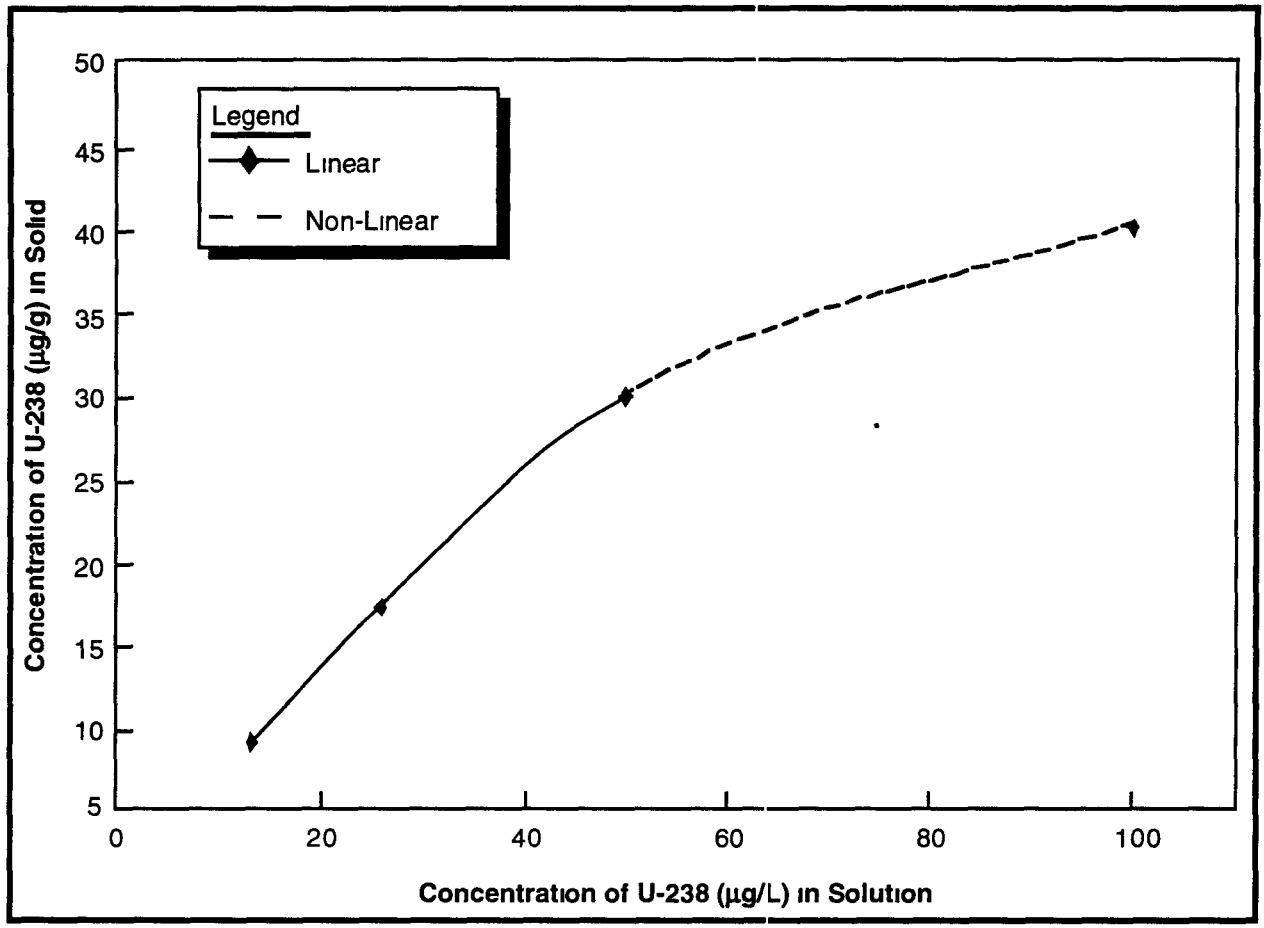

Figure 4.1.1.2-3 Uranium Isotherm for Bone Charcoal

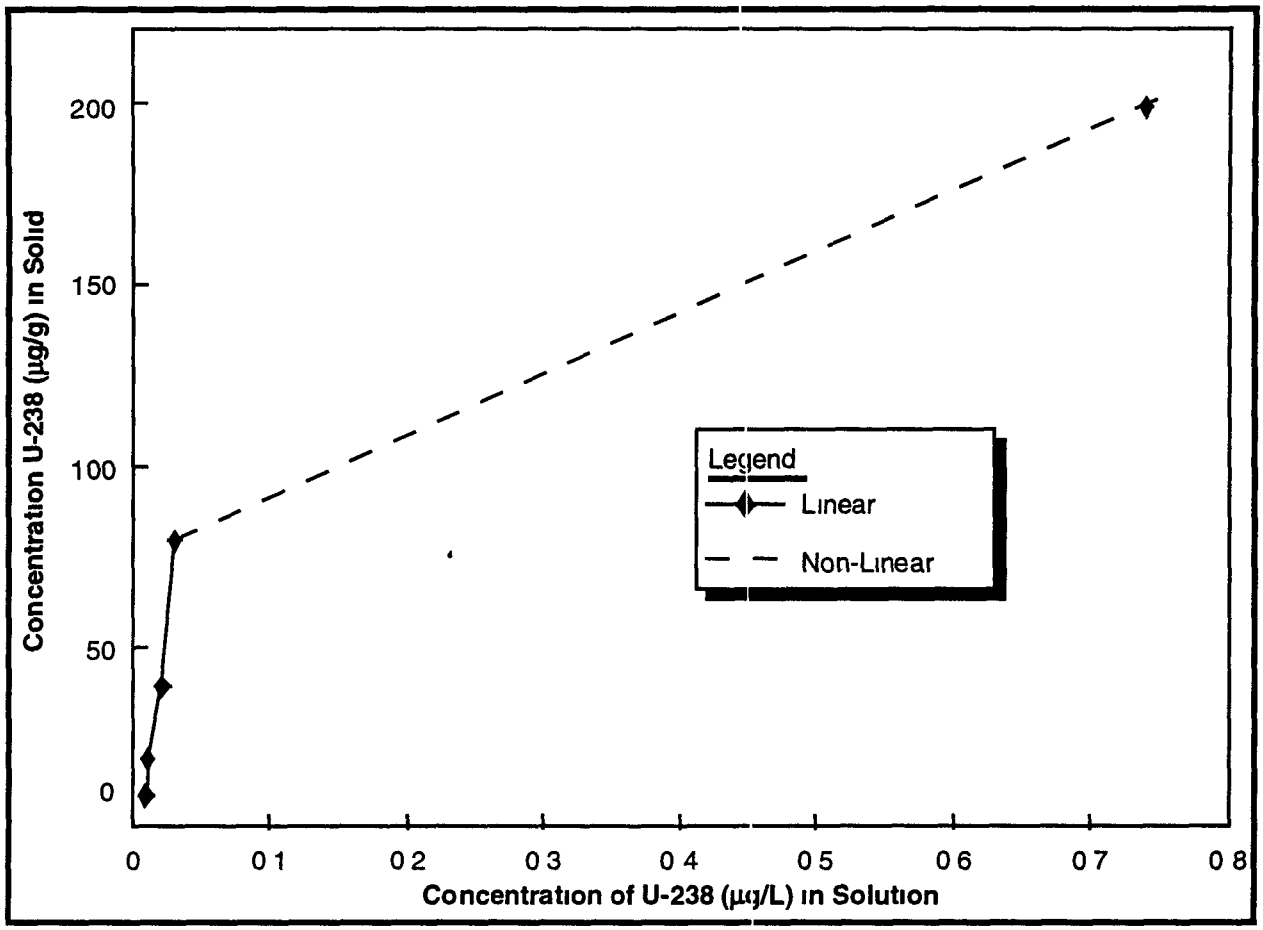

Figure 4 1 1.2-4 Uranium Isotherm for SORBPLUS

4.1.2 Well GW206789 for Selenium

The column tests consumed 2 to 3 liters of feed solution The batch tests required only 200 ml for the four adsorbent weight to solution rations tested for each adsorbent The selenium batch test results for the 1 50, 1 100, 1 200, and 1 400 ratios are shown in Table 4 1 2-1 The pH values are also included for comparison

High selenium values (500 to 700 µg/L) for the various adsorbent weight to solution volume ratios, except for SORBPLUS, indicated that selenium was not retained by the other five adsorbents (1) Bone Charcoal (R1022), (2) F-1 Alumina, (3) BIOFIX, (4) Natural Zeolite, and

(5) Filtrasorb 300 (granular activated charcoal), therefore, no column tests were performed for these adsorbents

*Table 4 1.2-1 Adsorption Experiments for Selenium (Batch)**

Feed Solution – Well B206789 Selenium 600 µg/L, pH 7 8 (Values are in µg/L)						
Solid Volume	F-1 Alumina	Bone Charcoal	BIOFIX	Zeolite	Active Carbon	SORBPLUS
1 50	680	610	660	680	620	<1
pH	8 3	8 3	7 9	8 2	8 1	11 6
1 100	580	700	630	640	500	56
pH	8 3	8 3	8 0	8 2	8 1	9 6
1 200	680	660	690	X	X	270
pH	8 2	8 2	8 1			8 1
1 400	660	X	X	X	X	395
pH	8 2					7 8

• 50 mL of feed solution was taken for each batch test

Se values are from Accu-Labs Research, Inc except for SORBPLUS

pH values are from EG&G

The high Se values are thought to be due to evaporation of solution over time prior to analysis The feed solution in this batch yielded a value of 680 µg/L

X No batch experiment was performed

A column test for SORBPLUS showed a selenium level of <1µg/L in the effluent (a RF of >600), with a pH of 11 6 However, in the batch tests, the influent/effluent ratio decreased sharply from the 1 50, 1 100, 1 200, and 1 400 ratios as did the corresponding batch Kd values (See Table 4 1 2-2) The high influent/effluent ratios (>600) for the column and batch tests (1 50) suggested that the adsorption equilibrium was reached in a residence time of 20 to 30 minutes

Table 4.1.2-2 Adsorption Experiments (Batch and Column) for Selenium

Selenium (µg/L)					
Ads Wt Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
SORBPLUS					
1 50	600	<1	>600	—	11 6
1 100	600	56	10 7	971	9 6
1 200	600	270	2 2	244	8 1
1 400	600	395	1 5	207	8 0
1 400*	600	460	1 3	122	8 0
Column Experiment					
	600	<1	>600		11 8
•	600	<5	>120		12 2

*Accu-Labs Research, Inc Data

$$\text{Batch Kd} = \frac{\text{Solid (µg/g)}}{\text{Liquid (µg/ml)}}$$

A solid (µg/g) versus liquid (µg/L) plot for the 1 100, 1 200, and 1 400 ratios are shown in Figure 4 1 2-1 It follows a linear isotherm with a shallow slope This suggests a low equilibrium batch Kd value, and thus low retention factor and loading capacity with a large volume of water Based on the slope, the batch Kd value is about 40 ml/g for selenium

SORBPLUS is effective for small adsorbent weight to solution volume ratios However, it is marginally effective with increased adsorbent weight to solution volume ratios This fact coupled with a high effluent pH makes SORBPLUS less attractive for selenium removal Groundwater Well B206789 had a selenium concentration of 600 µg/L With a batch Kd value of 40 ml/g, the selenium level could be reduced to 15 µg/L as compared to its potential ARAR value of 10 µg/L For and effective removal (>99 9 percent), a batch Kd of about 500 to 1000 is desirable

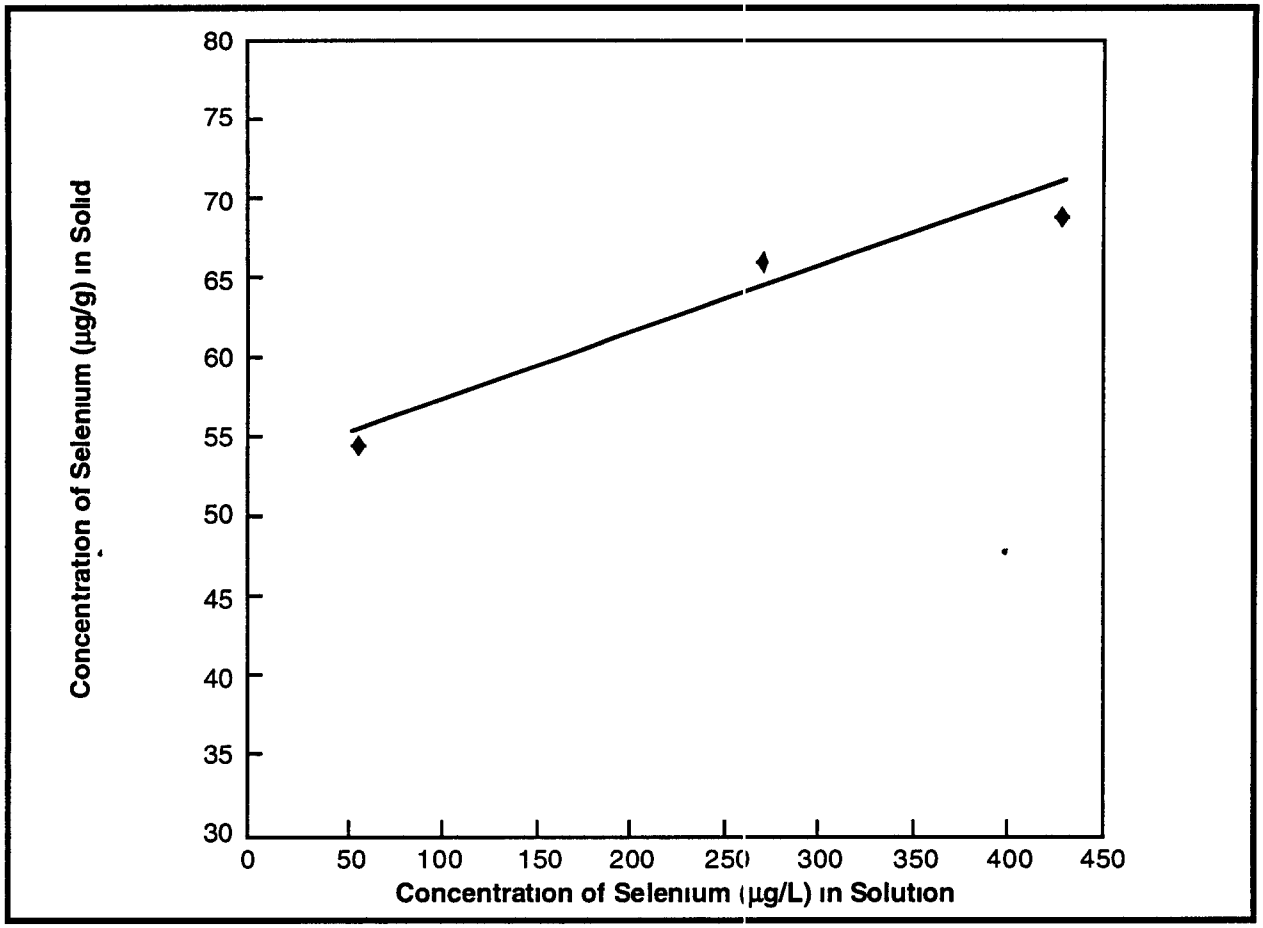

Figure 4 1 2-1 Selenium Isotherm for SORBPLUS

4.1.3 Analysis of Water Characteristics

GW3086 contained 66 7 pCi/L (200 µg/L) of uranium (U-238) Pu-239+240 and Am-241 concentrations were below their potential ARAR value of 0 05 pCi/L The COC (i e , Be, Cr, Fe, Pb, Mn, Hg, and Se) were also below their ARAR potential values The water samples major cationic and anionic compositions and TDS (mg/L) are shown in Table 1 2 1-1 The pH was 7 6, indicating a predominance of a bicarbonate medium

Well B206789 contained uranium, plutonium, and americium below their potential ARARs The COC (i e , Be, Cr, Fe, Pb, Mn, and Hg) were below their potential ARARs as well (See Appendix A) Only selenium was above its ARAR value of 10 µg/L with a concentration of 600 µg/L The

major cationic and anionic compositions are shown in Table 1 2 1-1 The water sample from Well B206789 contained three times less TDS (1200 mg/L) than the sample from Well GW2086 (3800 mg/L), which is reflected in lower cationic and anionic compositions (See Section 1 2 1) The pH of the samples was 7 8, which indicated a predominance of a bicarbonate medium

4.1.4 Analysis of Treatability Study Data

Using column and batch tests, the experiments focused on the removal of uranium from Well GW3086 and selenium from Well B206789 by the six adsorbents If the column tests did not retain uranium, then batch tests were not performed for that particular adsorbent For selenium, the batch tests were performed first These tests showed that only SORBPLUS was effective in removing selenium Subsequently, a single column test was only conducted with SORBPLUS For the column tests, the uranium content of the effluent, the retention factor and the pH were compared for all six adsorbents For the batch tests, the uranium concentration in the effluent, the retention factor, the Kd and pH were compared Also, the uranium concentration on the adsorbent versus its concentration in the liquid phase were plotted The batch Kd values and adsorption isotherm plots were used to characterize the adsorbents They are important for evaluating loading capacities and break-through curves of adsorbents in production operations

4.1.5 Comparison To Test Objectives

The objective of the TSWP was to test the effect of six adsorbents on removing uranium from groundwater at RFETS Results (See Tables 1 2 1-1 through 4 1 2-2) showed that four adsorbents removed uranium and one adsorbent, SORBPLUS, removed selenium from groundwater at RFETS Based on the RF and batch Kd values, F-1 Alumina and BIOFIX appeared to be best suited for removing uranium, while SORBPLUS marginally removed selenium from groundwater In spite of a high effluent pH (9 to 12), SORBPLUS was the only adsorbent that was effective in removing uranium and selenium from groundwater at RFETS Overall, the four adsorbents were effective in removing uranium to concentration below the potential ARAR value of 5 pCi/L or 15 µg/L column and batch experiments For selenium, only SORBPLUS was marginally effective in removing Se and, thus, may not meet the potential ARAR value of 10 µg/L

4.2 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

All the experiments were performed from the same homogenous feed solution, which avoided sampling variability Experimental conditions were kept constant to minimize any variability in these parameter (i e , solution feed rate, total effluent volume, column dimensions, sample size in batch tests, tumbling speed for batch tests, and equilibration time for batch tests) For EG&G Rocky Flats laboratory analysis, a set of calibrated standards were used for measuring pH, uranium, and selenium concentrations Duplicate analyses were performed to assess the experimental precision, which was approximately 10 percent for uranium and 10 to 20 percent for selenium QA/QC Level II was used in intermediate and final analysis of samples at EG&G Confirmation of some final results were obtained from Accu-Labs Research, Inc using QA/QC Level III

The samples were also analyzed by Accu-Labs Research, Inc , an EPA certified lab, for complete characterization of analytes such as pH, TSS, TDS, metals anions, and radionuclides Based on QA/QC, all the results in this report can be tracked and verified at EG&G and Accu-Labs Research, Inc

4.3 COSTS

A Work Plan was written and approved by DOE, CDH, and EPA to support this treatability study Following its approval, the work was initiated It included (1) water sampling (2 weeks), (2) ordering equipment and performing the column and batch experiments (12 weeks), (3) analysis of various analyte pH values, TDS, TSS, metals, anions, and radionuclides (i e , U-234, U-238, Pu-239+240, and Am-241) by Accu-Labs Research, Inc (12 weeks), and (4) data reduction and a written report (6 weeks) This study lasted approximately 10 months and cost approximately $130,000

Table 4 3-1 shows the costs of the various adsorbents by the respective manufacturers The costs ranged between $1 00/lb for F-1 Alumina to $2 50/lb for B OFIX The price also varied depending on the quantity ordered SORBPLUS, effective for uranium and selenium removal costs $2 00/lb and is available within 4 to 6 weeks All adsorbents are readily available given a 2 to 6

week advance notice As per manufacturer, these adsorbents can be regenerated and reused a number of times to maximize their use which is cost-effective and can minimize waste disposal problem , because of regeneration of the adsorbent and stripping metals and radionuclides

Table 4.3-1 Cost and Availability of Adsorbents

Manufacturer	Adsorbent	Cost	Availability
ALCOA Industrial Chemical	SORBPLUS	$2 00/lb	4 – 6 Weeks
ALCOA Industrial Chemical	F-1 Alumina	$1 30 – $1 03/lb (Depending on Quantity)	2 – 4 Weeks
Harrison Western Environmental Services	BIOFIX	$2 50/lb	2 – 4 Weeks
Calgon Carbon Corp	Filtrasorb-300 (Activated Carbon)	$1 50/lb	2 – 6 Weeks
Rockland International	Bone Charcoal (R1022)	$3 40 – $2 10/lb (Depending on Quantity)	2 – 4 Weeks
East-West Minerals*	Zeolite	No Information Available	
*The Company No Longer Exists			

4.4 Key Contacts

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M C Rupert
Environmental Engineering & Technology
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Golden, Colorado 80402
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Appendix A

Analytical Data from Accu-Labs Research, Inc., Golden, Colorado

Accu-Labs® Research, Inc.
663 Table Mountain Drive Golden, Colorado 80403 1650
(303) 277 9514 FAX (303) 277 9512

A N A L Y S I S R E P O R T

DATE: 06/09/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P.O. BOX 464, BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-54257-8
Date Samples Received: 05/13/94
Customer PO Number: ASC233268J03

These samples will be disposed of 30 days after the date of this report.

ALR Designation -	2426-54257-8-1	2426-54257-8-2	2426-54257-8-3
Sponsor Designation -	3086-UNFIL	3086-FIL	3086-ACT CHARCOAL
Date Collected -	04/19/94	04/19/94	04/27/94

Determinations in pCi/L unless noted

Uranium-234 - dissolved	--N/A--	140 ± 10	110 ± 10
Uranium-234 - total	120 ± 20	--N/A--	--N/A--
Uranium-238 - dissolved	--N/A--	90 ± 10	71 ± 10
Uranium-238 - total	78 ± 13	--N/A--	--N/A--
Plutonium-239+240 - dissolved	--N/A--	0.01 ± 0.02	--N/A--
Plutonium-239+240 - total	0.00 ± 0.01	--N/A--	--N/A--
Americium-241 - dissolved	--N/A--	-0.01 ± 0.03	--N/A--
Americium-241 - total	-0.01 ± 0.03	--N/A--	--N/A--
Uranium - dissolved (mg/L)	--N/A--	0.19	0.16
Uranium - dissolved (rerun) (mg/L)	--N/A--	--N/A--	--N/A--
Uranium - total (mg/L)	0.20	--N/A--	--N/A--

A N A L Y S I S R E P O R T

DATE: 06/09/94 PAGE 2

Lab Job Number 2426-54257-8

ALR Designation -	2426-54257-8-4	2426-54257-8-5	2426-54257-8-6
Sponsor Designation -	3086-BONE CHARCOAL	3086-ALUMINA	3086-SORBPLUS
Date Collected -	04/27/94	04/27/94	04/27/94

Determinations in pCi/L unless noted

Uranium-234 - dissolved	0.2 ± 0.2	0.0 ± 0.1	0.1 ± 0.1
Uranium-234 - total	--N/A--	--N/A--	--N/A--
Uranium-238 - dissolved	-0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.1
Uranium-238 - total	--N/A--	--N/A--	--N/A--
Plutonium-239+240 - dissolved	--N/A--	--N/A--	--N/A--
Plutonium-239+240 - total	--N/A--	--N/A--	--N/A--
Americium-241 - dissolved	--N/A--	--N/A--	--N/A--
Americium-241 - total	--N/A--	--N/A--	--N/A--
Uranium - dissolved (mg/L)	0.0005	<0.0001	<0.0001
Uranium - dissolved (rerun) (mg/L)	0.00032	0.00003	0.00002
Uranium - total (mg/L)	--N/A--	--N/A--	--N/A--

A N A L Y S I S R E P O R T

DATE: 06/09/94 PAGE 3

Lab Job Number 2426-54257-8

ALR Designation -	2426-54257-8-7	2426-54257-8-8
Sponsor Designation -	3086-ZEOLITE	3086-BIOFIX
Date Collected -	05/02/94	05/06/964

Determinations in pCi/L unless noted

Uranium-234 - dissolved	100 ± 10	0.2 ± 0.1
Uranium-234 - total	--N/A--	--N/A--
Uranium-238 - dissolved	65 ± 9	0.0 ± 0.1
Uranium-238 - total	--N/A--	--N/A--
Plutonium-239+240 - dissolved	--N/A--	--N/A--
Plutonium-239+240 - total	--N/A--	--N/A--
Americium-241 - dissolved	--N/A--	--N/A--
Americium-241 - total	--N/A--	--N/A--
Uranium - dissolved (mg/L)	0.18	0.0008*
anium - dissolved (rerun) (mg/L)	--N/A--	0.00016
Uranium - total (mg/L)	--N/A--	--N/A--

*Probable Contamination

By: Bud Summers

Bud Summers
Radiochemistry Supervisor

BS/rtd

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Batch 1 400

June 16, 1994

Mr. J.C. Laul
EG & G Rocky Flats, Inc.
Rocky Flats Plant
Bldg. 080
P.O. Box 464
Golden, co 80402-0464

RE: 2426-54678-4
Date Samples Rec'd 6-3-94
P.O. No. ASC233268J03

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	2426-54678-4-1 Bone Charcoal 5-28-94	2426-54678-4-2 Alumina 5-28-94
Determination: pCi/L		
Uranium-234, dissolved, ± counting error*	58 ± 3	6.9 ± 0.8
Uranium-238, dissolved, ± counting error*	35 ± 3	4.4 ± 0.7
Uranium by KPA, total, µg U/L	87	12
Uranium by KPA, total, µg U/L (Rerun analysis)	110	--

Accu-Labs Research, Inc.

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	2426-54678-4-3 Sorbplus 5-28-94	2426-54678-4-4 Biofix 5-29-94
Determination: pCi/L		
Uranium-234, dissolved, ± counting error*	--	1.5 ± 0.4
Uranium-238, dissolved, ± counting error*	--	0.9 ± 0.3
Uranium by KPA, total, µg U/L	0.02	3.3
Uranium by KPA, total, µg U/L (Rerun analysis)	0.03	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be discarded 30 days after the date of this report.

for Bud Summers
Radiochemistry Supervisor

BS/dh

Accu-Labs® Research, Inc.
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ANALYSIS REPORT

DATE: 08/02/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-55335-12
Date Samples Received: 07/07/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335- 2-2
Sponsor Designation -	8206789	8206789
Comments -	UNFILTERED	FILTERED
Date Collected -		

Determinations in mg/L unless noted

Silver - dissolved	----	<0 005
Silver - total	<0 005	----
Aluminum - dissolved	----	<0 1
Aluminum - total	0 3	----
Barium dissolved	----	<0 05
Barium - total	<0 05	----
Beryllium - dissolved	----	<0.005
Beryllium - total	<0 005	----
Calcium - dissolved	----	160
Calcium - total	150	----
Cadmium - dissolved	----	<0.005
Cadmium - total	<0 005	----
Cobalt - dissolved	----	<0 005
Cobalt total	<0 005	----
Chromium - dissolved	----	<0 005
Chromium - total	<0 005	---
Copper - dissolved	----	<0.005
Copper - total	<0.005	---
Iron - dissolved	----	0.11
Iron - total	0.30	----
Potassium - dissolved	----	3.6
Potassium - total	3.3	----
Lithium - dissolved	----	0 22
Lithium - total	0.20	----
Magnesium - dissolved	----	44

ANALYSIS REPORT
DATE: 08/02/94 PAGE 2
Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2
Sponsor Designation -	B206789	B206789
Comments -	UNFILTERED	FILTERED
Date Collected -		

Determinations in mg/L unless noted

Magnesium - total	41	----
Manganese - dissolved	----	<0.005
Manganese - total	0 007	----
Molybdenum - dissolved	----	<0 01
Molybdenum - total	<0 01	----
Sodium - dissolved	----	140
Sodium - total	130	- --
Nickel - dissolved	----	<0 02
Nic el - total	<0 02	- --
mony - dissolved	----	<0.05
Antimony - total	<0 05	----
Thallium - dissolved	----	<0 1
Thallium - total	<0 1	----
Vanadium - dissolved	----	<0 005
Vanadium - total	<0 005	----
Zinc - dissolved	----	<0.005
Zinc - total	0 024	----
Alkalinity, Total (as CaCO3 to pH 4 5)	180	180
pH (pH Units)	8.0	7.9
Arsenic - dissolved	----	<0.005
Arsenic - total	<0 005	---
Mercury - dissolved	----	0 0001
Mercury - total	<0.0001	---
Lead - dissolved	----	<0 005
Lead - total	<0 005	---

A N A L Y S I S R E P O R T
DATE: 08/02/94 PAGE 3
Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date or this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2
Sponsor Designation -	8206789	8206789
Comments -	UNFILTERED	FILTERED
Date Collected -		

Determinations in mg/L unless noted

Selenium - dissolved	----	0 60
Selenium - total	0 66	----
Nitrate (as N)	6 8	6 7
Total Dissolved Solids (@180 °C)	1,200	1,200
Total Suspended Solids (@105 °C)	18	-- -
Chloride	74	72
Sulfate (as SO4)	590	590

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ANALYSIS REPORT

DATE: 06/01/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-54257-8
Date Samples Received: 05/13/94
Customer PO Number· ASC233268JO3

These samples to be disposed of 30 days after the date of this report

	ALR Designation -	2426-54257-8-1	2426-54257 8-2	2426-54257-8-3	2426-54257-8-4
	Sponsor Designation -	3086-UNFIL	3086-FIL	3086-ACT CHARCOAL	3086-BONE CHARCOAL
	Date Collected -	04/19/94	04/19/94	04/27/94	04/27/94
Determinations in mg/L unless noted					
Silver - dissolved		----	<0 005	<0.005	<0 005
Silver - total		<0 005	----	----	----
Aluminum - dissolved		----	<0.1	<0.1	<0.1
Aluminum - total		3 8	----	----	----
Barium - dissolved		----	0.07	0 09	0.09
arium - total		0 08	---	----	----
Beryllium - dissolved		----	<0 005	<0 005	<0 005
[illegible]lium - total		<0 005	---	----	----
[illegible]ium - dissolved		----	290	240	92
Calcium - total		260	---	----	----
Cadmium - dissolved		----	<0.005	<0 005	<0.005
Cadmium - total		<0 005	----	----	----
Cobalt - dissolved		----	<0.005	0.005	<0 005
Cobalt - total		<0 005	----	----	----
Chromium - dissolved		----	<0 005	<0 005	<0 005
Chromium - total		0 011	---	----	----
Copper - dissolved		----	<0.005	<0.005	<0 005
Copper - total		0.005	----	----	----
Iron - dissolved		----	<0 01	0.15	<0.01
Iron - total		1 6	-- -	----	----
Potassium - dissolved		----	31	32	36
Potassium - total		39	-- -	----	----
Lithium - dissolved		----	0 63	0.61	0.57
Lithium - total		0.58	-- -	----	----
Magnesium - dissolved		----	83	85	130

ANALYSIS REPORT
DATE: 06/01/94 PAGE 2
Lab Job Number 2426-54257-8

These samples to be disposed of 30 days after the date of this report

ALR Designation -	2426-54257-8-1	2426-54257-8-2	2426-54257-8-3	2426-54257-8-4
Sponsor Designation -	3086-UNFIL	3086-FIL	3086-ACT CHARCOAL	3086-BONE CHARCOAL
Date Collected -	04/19/94	04/19/94	04/27/94	04/27/94
Determinations in mg/L unless noted				
Magnesium - total	76	-- -	----	----
Manganese - dissolved	----	<0 005	0.049	<0 005
Manganese - total	0 013	-- -	----	----
Molybdenum - dissolved	----	<0 01	<0 01	<0.01
Molybdenum - total	0 01	-- -	----	----
Sodium - dissolved	----	650	670	690
Sodium - total	630	----	----	----
Nickel - dissolved	----	<0 02	<0 02	<0 02
Nickel - total	<0.02	----	----	----
Antimony - dissolved	----	<0 05	<0 05	<0 05
Antimony - total	<0 05	----	----	----
[illegible]ium - dissolved	----	<0.1	0.1	<0.1
[illegible]ium - total	0 1	- --	----	----
Vanadium - dissolved	----	<0 005	0 006	<0.005
Vanadium - total	0 007	- --	----	----
Zinc - dissolved	----	<0.005	<0.005	<0 005
Zinc - total	0 008	- --	----	----
Alkalinity, Total (as CaCO3 to pH 4 5)	400	320	240	280
Carbonate (as CO3)	<5	<5	<5	<5
Bicarbonate (as HCO3)	480	390	300	340
pH (pH Units)	7.7	7.5	7.7	8.3
Arsenic - dissolved	----	<0.005	0.010	<0.005
Arsenic - total	<0.005	----	----	----
Mercury - dissolved	----	<0.0001	<0.0001	<0.0001
Mercury - total	0.0001	---	----	----
Lead - dissolved	----	0 005	<0.005	<0.005
Lead - total	<0.005	---	----	----
Selenium - dissolved	----	0 005	<0.005	<0.005
Selenium - total	<0.005	---	----	----
Nitrate (as N)	510	500	560	550

A N A L Y S I S R E P O R T

DATE: 06/01/94 PAGE 3

Lab Job Number 2426-54257-8

These samples to be disposed of 30 days after the date of this report.

	ALR Designation -	2426-54257-8-1	2426-54257-8-2	2426-54257-8-3	2426-54257-8-4
	Sponsor Designation -	3086-UNFIL	3086-FIL	3086-ACT CHARCOAL	3086-BONE CHARCOAL
	Date Collected -	04/19/94	04/19/94	04/27/94	04/27/94
Determinations in mg/L unless noted					
Total Dissolved Solids (@180 °C)		3,800	4,000	3,500	3,500
Total Suspended Solids (@105 °C)		74	-- -	----	----
Chloride		110	120	120	110
Sulfate (as SO4)		220	230	210	190

A N A L Y S I S R E P O R T

DATE. 06/01/94 PAGE 4

Lab Job Number 2426-54257-8

These samples to be disposed of 30 days after the date of this report.

	ALR Designation -	2426-54257-8-5	2426-54257-8-6	2426-54257-8-7	2426-54257-8-8
	Sponsor Designation -	3086-ALUMINA	3086-SORBPLUS	3086-ZEOLITE	3086-BIOFIX
	Date Collected -	04/27/94	04/27/94	05/02/94	05/06/94
Determinations in mg/L unless noted					
Silver - dissolved		<0 005	<0 005	<0 005	<0 005
Aluminum - dissolved		0.5	0 3	<0.1	<0 1
Barium - dissolved		<0 05	<0 05	<0.05	0 05
Beryllium - dissolved		<0 005	<0 005	<0 005	<0.005
Calcium - dissolved		140	140	100	150
Cadmium - dissolved		<0.005	<0 005	<0 005	<0.005
Cobalt - dissolved		<0 005	<0.005	<0 005	<0 005
Chromium - dissolved		<0.005	<0 005	<0.005	<0 005
Copper - dissolved		<0.005	<0.005	0 006	<0 005
Iron - dissolved		<0.01	<0 01	<0 01	<0 01
Potassium - dissolved		32	32	26	33
[illegible] - dissolved		0.48	0 44	0 59	0 61
[illegible]sium - dissolved		65	1.4	78	76
Manganese - dissolved		<0.005	<0.005	<0 005	<0.005
Molybdenum - dissolved		<0 01	<0.01	<0.01	<0 01
Sodium - dissolved		700	670	790	690
Nickel - dissolved		<0.02	<0.02	<0 02	<0 02
Antimony - dissolved		<0 05	<0 05	<0.05	<0 05
Thallium - dissolved		<0 1	<0.1	0.1	0 2
Vanadium - dissolved		<0 005	<0 005	<0 005	<0.005
Zinc - dissolved		<0 005	<0.005	<0.005	<0.005
Alkalinity, Total (as CaCO3 to pH 4 5)		180	1,800	260	120
Carbonate (as CO3)		<5	12	<5	<5
Bicarbonate (as HCO3)		220	<5	320	150
pH					
(pH Units)		8.1	12.6	8.0	7.4
Arsenic - dissolved		<0.005	<0 005	<0.005	<0.005
Mercury - dissolved		<0 0001	<0 0001	<0.0001	<0.0001
Lead - dissolved		<0.005	0 007	<0.005	<0.005
Selenium - dissolved		<0.005	<0 005	<0.005	<0.005
Nitrate (as N)		560	<0 05	540	530

ANALYSIS REPORT

DATE: 06/01/94 PAGE 5

Lab Job Number 2426-54257-8

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-54257-8-5	2426-54257-8-6	2426-54257-8-7	2426-54257-8-8
Sponsor Designation -	3086-ALUMINA	3086-SORBPLUS	3086-ZEOLITE	3086-BIOFIX
Date Collected -	04/27/94	04/27/94	05/02/94	05/06/94
Determinations in mg/L unless noted				
Total Dissolved Solids (@180 °C)	3,600	1,800	4,100	3,700
Chloride	120	3	120	120
Sulfate (as SO4)	80	<10	200	210

By: Eyda Hergenreder
Eyda Hergenreder
Metals Laboratory Supervisor

By: Susan J Barker
Susan J. Barker
Inorganic Chemistry Supervisor

EH/SJB/rt

Accu-Labs® Research, Inc.
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Batch 1 400

ADDITIONAL REPORT

ANALYSIS REPORT

DATE: 08/01/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-54678-4
Date Samples Received: 06/03/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-54678-4-1	2426-54678-4-2	2426-54678-4-3	2426-54678-4-4
Sponsor Designation -	BONE CHARCOAL	ALUMINA	SORBPLUS	BIOFIX
Date Collected -	05/28/94	05/28/94	05/28/94	05/29/94
Determinations in mg/L unless noted				
Silver - dissolved	<0 005	<0 005	<0 005	<0 005
Aluminum - dissolved	<0 1	0 1	<0 1	<0 1
Barium - dissolved	0.09	<0.05	0.05	0.07
Beryllium - dissolved	<0 005	<0.005	<0 005	<0 005
Calcium - dissolved	150	160	87	150
Cadmium - dissolved	<0 005	<0 005	<0.005	<0.005
Cobalt - dissolved	<0 005	<0 005	<0 005	<0 005
[illegible]um - dissolved	<0 005	<0.005	<0.005	<0 005
[illegible]r - dissolved	<0 005	<0.005	<0 005	<0 005
Iron - dissolved	<0 01	<0 01	<0 01	<0 01
Potassium - dissolved	37	35	35	34
Lithium - dissolved	0 60	0.59	0 57	0.59
Magnesium - dissolved	87	79	70	77
Manganese - dissolved	<0 005	<0 005	<0 005	<0.005
Molybdenum - dissolved	<0 01	<0 01	<0 01	<0 01
Sodium - dissolved	640	620	620	630
Nickel - dissolved	<0 02	<0 02	<0.02	<0.02
Antimony - dissolved	<0.05	<0 05	<0.05	<0.05
Thallium - dissolved	<0.1	<0 1	<0.1	<0.1
Vanadium - dissolved	0.005	<0 005	<0.005	0.005
Zinc - dissolved	<0.005	<0 005	<0.005	<0.005
Alkalinity, Total (as CaCO3 to pH 4.5)	* [16]	* [16]	* [16]	* [16]
Carbonate (as CaCO3)	* [16]	* [16]	* [16]	* [16]
Bicarbonate (as HCO3)	* [16]	* [16]	* [16]	* [16]
pH (pH Units)	7 9	7 5	8.2	7.5

ANALYSIS REPORT

DATE: 08/01/94 PAGE 2

Lab Job Number 2426-54678-4

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-54678-4-1	2426-54678-4-2	2426-54678-4-3	2426-54678-4-4
Sponsor Designation -	BONE CHARCOAL	ALUMINA	SORBPLUS	BIOFIX
Date Collected -	05/28/94	05/28/94	05/28/94	05/29/94
Determinations in mg/L unless noted				
Arsenic - dissolved	<0.005	<0 005	<0 005	<0 005
Mercury - dissolved	<0 0001	<0 0001	<0.0001	<0 0001
Lead - dissolved	<0 005	<0 005	<0 005	<0 005
Selenium - dissolved	<0 025 [9]	<0 025 [9]	<0 025 [9]	<0 025 [9]
Nitrate + Nitrite	640 [16]	760 [16]	640 [16]	720 [16]
Total Dissolved Solids (@180 °C)	3,700	3,700	3,500	3,700
Chloride	120 [16]	150 [16]	110 [16]	140 [16]
Sulfate (as SO4)	150 [16]	160 [16]	. 58 [16]	160 [16]

Notes:

[16] -- ADDITIONAL VALUE

[9] -- HIGHER D.L. DUE TO SAMPLE MATRIX INTERFERENCE

*Unable to report due to depletion of samples.

By: Eyda Hergenreder

Eyda Hergenreder
Metals Laboratory Supervisor

By: Susan J. Barber

Susan J. Barber
Inorganic Chemistry Supervisor

EH/SJB/rd

Accu-Labs® Research, Inc.

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ANALYSIS REPORT

DATE: 08/18/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-55924-2
Date Samples Received: 08/09/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55924-2-1	2426-55924-2-2
Sponsor Designation -	SORBPLUS COLUMN	SORBPLUS (1 400)
Comments -	B206789(SE)	B206789(SE)
Date Collected -		07/30/94

Determinations in mg/L unless noted

Silver - total	<0.005	<0 005
Aluminum - total	1.4	<0.1
Barium - total	<0.05	<0 05
Beryllium - total	<0 005	<0 005
Calcium - total	120	3[illegible]
[illegible]mium - total	<0 005	<0 005
[illegible]alt - total	<0 005	<0 005
[illegible]hromium - total	0 005	<0.005
Copper - total	<0.005	<0.005
Iron - total	<0 01	<0 01
Potassium - total	3 6	3 0
Lithium - total	0.12	0 20
Magnesium - total	3 3	31
Manganese - total	<0.005	0.005
Molybdenum - total	<0 01	0 01
Sodium - total	140	140
Nickel - total	<0.02	<0.02
Antimony - total	<0.05	<0.05
Selenium - total	<0.05	0.46
Thallium - total	<0.1	<0.1
Vanadium - total	0.005	<0.005
Zinc - total	<0.005	<0.005
Alkalinity, Total (as CaCO3 to pH 4.5)	650	60
pH		
(pH Units)	12.2	8.0

ANALYSIS REPORT

DATE: 08/18/94 PAGE 2

Lab Job Number 2426-55924-2

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55924-2-1	2426-55924-2-2
Sponsor Designation -	SORBPLUS COLUMN	SORBPLUS (1 400)
Comments -	B206789(SE)	B206789(SE)
Date Collected -		07/30/94

Determinations in mg/L unless noted

Arsenic - total	<0.005	<0.005
Mercury - total	<0 0001	<0.0001
Lead - total	<0 005	<0 005
Selenium - total	<0.005	0 44
Nitrate (as N)	<0 05	7 0
Total Dissolved Solids (@180 °C)	640	800
Chloride	<3	70
Sulfate (as SO4)	<10	410

By: Eyda Hergenreder
Eyda Hergenreder
Metals Laboratory Supervisor

By: Susan J Barker
Susan J. Barker
Inorganic Chemistry Supervisor

EH/SJB/rt

Re: 2426-55924-2

QC INFORMATION

For Selenium

Duplicate (%RPD)

	#1
ICP	0
HGA	0

Spike

The spiking concentration for HGA was 0.050 mg/L and 0.5 mg/L for ICP. The samples were post digested spiked for both ICP and HGA.

	#1	#2
ICP	96%	102%
HGA	100%	100%

Reagent Blank

ICP	<0.05 mg/L
HGA	<0.005 mg/L

Laboratory Control Sample

ICP	90% (TV = 1.0 mg/L)
HGA	101% (TV = 0.080 mg/L)

Accu-Labs® Research, Inc.

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October 5, 1994

J.C. Laul
EG&G Rocky Flats
Environmental Technology Site
POB 464 Bldg 881
Golden, CO 80402-0464

RE: 2426-56485-36A
Date Samples Rec'd 9-8-94
P.O. No. ASC233268J03

REPORT OF ANALYSIS

ALR Designation	2426-56485-36A-1	2426-56485-36A-2	2426-56485-36A-4
Sponsor Designation	Feed Solution	Sorbplus (1:50)	Sorbplus (1:200)
Determination: mg/L			
Selenium, dissolved	0.68	<0.005	0.27

ALR Designation	2426-56485-36A-5	2426-56485-36A-6	2426-56485-36A-7
Sponsor Designation	F-1 Aluminum 1:50	F-1 Aluminum 1:100	Aluminum 1:200
Selenium, dissolved	0.68	0.58	0.68

ALR Designation	2426-56485-36A-8	2426-56485-36A-9	2426-56485-36A-10
Sponsor Designation	F-1 Aluminum 1:400	Bone Charcoal 1:50	Bone Charcoal 1:100
Selenium dissolved	0.66	0.61	0.72

REPORT OF ANALYSIS

ALR Designation	2426-56485-36A-11	2426-56485-36A-12	2426-56485-36A-13
Sponsor Designation	Bone Charcoal 1:200	Biofix (1:50)	Biofix (1:100)
Determination: mg/L			
Selenium, dissolved	0.66	0.66	0.63

ALR Designation	2426-56485-36A-14	2426-56485-36A-15	2426-56485-36A-16
Sponsor Designation	Biofix (1:200)	Zeolite (1:50)	Zeolite (1:100)
Selenium, dissolved	0.69	0.68	0.64

ALR Designation	2426-56485-36A-17	2426-56485-36A-18
Sponsor Designation	Activated Carbon	Activated Carbon
Selenium, dissolved	0.62	0.50

These samples are scheduled to be discarded 30 days after the date of this report.

Eyda Hergenreder
Eyda Hergenreder
Metals/RCRA Supervisor

EH/ep

Appendix B

Acronym List

Am	Americium
ARAR	Applicable or Relevant and Appropriate Requirements
Be	Beryllium
Ca	Calcium
cc	cubic centimeters
CDPHE	Colorado Department of Public Health and Environment
COC	Contaminants of Concern
Cr	Chromium
DOE	Department of Energy
EPA	Environmental Protection Agency
ERPD	Environmental Restoration Program Division
Fe	Iron
FS	Feasibility Study
ft	feet
GFAA	Graphite Furnace Atomic Adsorption
HCl	Hydrochloric Acid
Hg	Mercury
K	Potassium
Kacl	Weathered Claystone
Kass	Unweathered Sandstone
mg/L	Milligrams per Liter
µg/g	Micrograms per Gram
µg/L	Micrograms per Liter
Mg	Magnesium
ml/min	Milliliters per Minute
µm	Microns or Micrometers

Mn	Manganese
Na	Sodium
NaOH	Sodium Hydroxide
ng/mL	Nanograms per Milli iter
Pb	Lead
pCi/L	Picocuries per Liter
pH	Hydrogen ion concentration
ppb	part per billion
Pu	Plutonium
QA/QC	Quality Assurance/Quality Control
RF	Retention Factor
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFFO	Rocky Flats Field Office
Se	Selenium
SEP	Solar Evaporation Pond
STSP	Sitewide Treatability Studies Program
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
TSWP	Treatability Study Work Plan
U	Uranium